SCIENTIFIC HISTORY AND FUTURE USES OF WIRELESS TELEGRAPHY.

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PUBLIC attention, on both sides of the Atlantic, has recently been strongly directed to the possibilities of telegraphy through space, by the remarkable experiments of Signor G. Marconi. Taking advantage of well known scientific principles, together with very important and novel additions of his own, this ingenious inventor has startled the world by flinging telegraphic messages across thirty miles of sea, wrapt, it may be, in fog, or swept by storm, and recording, in the well known Morse telegraphic alphabet of dot and dash, the communications thus conveyed without continuous connecting wires or cables of any kind. Every thoughtful person desires to gain some glimpse of the means by which this feat has been performed, and some little guidance in prognosticating the future of the new telegraphy.

It is very seldom that a new scientific departure is rightly apprehended at first, in regard either to its uses or its methods.

Imagination is often carried captive by a novel process, and a speedy revolution of old methods is anticipated; or, on the other hand, it is decried as containing nothing new, and the inventor is set down as a mere user of other people's ideas. An inventor, be it remarked in passing, is not necessarily a person who does anything new. He is often one chiefly gifted with that poetic insight which enables him to carry out to their true logical issue familiar facts, or he casts a sudden flood of light on well known processes by some simple adaptation of known means.

In the present instance, this wonderful conveyance of intelligence through space by electrical means, between places not con-

nected by the ordinary telegraphic wires, is the crowning achievement in a long series of scientific labors, the product of many minds and the outcome and reward of profound research.

Thoroughly to grasp the details and meaning of the whole process requires a scientific training and much acquaintance with physical research. It is, however, quite possible to convey a fairly correct notion of the nature of the operations involved to an ordinary reader who has patience to follow the argument.

Modern scientific research has conducted us to a position from which we see that the phenomena of the physical universe indicate three fundamental sources of all observed events, which form the underlying basis of the physical actions concerning which our senses inform us.

These great actualities are, respectively, matter, energy and ether. It is perfectly impossible to give any independent definitions of these things which shall be satisfactory to the metaphysician. Collectively speaking, the material objects we can handle and see, are, from the modern standpoint, the vehicles of energy in various forms; and every chemical or physical change we notice or can produce, is an exhibition of the changes in something called energy, associated with that which we call matter. A discussion of how far matter is entitled to a separate recognition, apart from energy, would be foreign to our present purpose, and would in any case plunge us into the seething caldron of metaphysical discussion. The chief fact of importance here necessary to note is, that the research of the present century has shown that large quantities of energy can be conveyed through space, or associated with that which we call a perfect vacuum. Hence has grown up the notion that space may not really be empty, but may have everywhere in it something which, like tangible matter, can be the vehicle of energy, though not possessing those qualities of ponderability, or power to affect directly our sense of touch, which characterizes that which we generally call material substance. This space-filling, non-material vehicle of energy is called the ether; and it is one of the most suggestive of modern physical conceptions, that the atoms which build up ordinary matter may even be only ether—in certain states of localized strain or motion. Leaving, however, the confines of speculation, we may say that the tendency of present day physical theory is to find, as our ultimate elements of analysis, in

dissecting the phenomena of the external world, three things, viz.: energy, ether and matter; all by us unalterable in total amount, but all susceptible of certain transformation, and each, by its interactions with the others, contributing to the processes which are the immediate precursors of our sense perceptions. The deeper we penetrate into the facts of Nature, the more we see that the only things we have a right to call real things lie far beneath the immediate objects of cognition.

Hence, research has wended its way by slow steps to that position from which we are able to recognize the validity of the assumption of a space-occupying ether, which now fills such an important position in existing physical hypotheses. Moreover, it has advanced from a position in which it was a mere vague speculation, called in, as it were, to cover up the difficulties involved in analyzing physical processes, to a position in which many converging lines of argument demand its postulation as a basis for the adequate explanation of effects.

The most philosophical minds have, however, always felt that, if the facts in more than one branch of physics separately taken seemed to necessitate the assumption of an ether, then it would be necessary to make the fundamental assumptions wide enough to make one ether sufficient for the explanation of all effects. Modern science has, therefore, banished all notions of manifold imponderable fluids; but, on the other hand, has deepened and strengthened the foundations on which has been built the hypothesis of one single sufficient ether. Now, this physical hypothesis grew up originally out of a study of optical phenomena; but the consideration of electrical and magnetic effects little by little forced physicists to the conclusion that luminous and electro-magnetic effects must be due to the same fundamental causes, and must therefore depend on the same ether.

When Prof. James Clerk Maxwell died at Cambridge, in November, 1879, he left as his most splendid intellectual legacy to the world his remarkable Electro-magnetic Theory of Light. At the beginning of the century, the original mind of Thomas Young, Professor of Natural Philosophy in the Royal Institution, had laid a firm grasp upon this scientific hypothesis of an all pervading medium or ether, as an assumption which was necessitated by a critical study of optical facts. That conjecture was, by no means, a novel one. The notion of imponderable fluids or

ethers had been a familiar one to natural philosophers, long before the researches of Young supplied fresh arguments for entertaining it as especially applicable in the case of optical effects. While we are probably indebted to Huyghens for first raising the conception of a luminous ether out of the dust of mere speculation to the level of a serious scientific hypothesis, it was by the researches of Young and his brilliant successors, among whom we may chiefly mention Fresnel, that it was placed upon the level of a theory to be tested and tried by the comparison of careful observations with mathematical deductions from the theory. The known fact that a ray of light takes time to travel from one place to another, and that this velocity, of about a thousand million feet a second, is everywhere and always the same, can only be explained in one of two ways. Either light must be a substance, emitted by luminous agents, which moves bodily from one place to another, or else it must be an action, transmitted from place to place through a medium. The crucial test which enabled a critical decision to be made between these two assumptions, was supplied by a principle first made known by Young. Without entering into highly technical details, suffice it to say that, under proper conditions, two rays of light, falling together on the same spot, may actually produce darkness instead of enhanced luminosity. In other words, light added to light may result in an absence of light. We are not able to conceive of any manner in which identical substances could thus annihilate each other, but we are abundantly familiar with cases in which one motion can destroy an equal and opposite motion, or a pressure or force annul an equal and opposite pressure or force.

Moreover, all subsequent investigation has shown that, along the path followed by a ray of light, there is some kind of periodical change or action constantly repeated, and also simultaneously occurring at certain regular intervals. In the early and middle parts of this century, experimentalists and mathematicians built up a body of irrefutable proof that the agent we call light must consist, in some kind, of very rapid and repeated change taking place in a universe-filling medium. For instance, along the path of a ray of light which produces a sensation of red when it falls upon our eyes, the same kind of changes or actions are being repeated at any one point about 400 billion times a second, and the same actions are being simultaneously performed at

places about one forty-thousandth of an inch apart. The former number is called the *frequency* of the light, and the latter its *wave-length.* The process of handing on from point to point this particular kind of action or motion is called a wave-motion, and the speed with which it is propagated is called the wave velocity. It is impossible to do more here than merely enunciate the fact, that no optical effects, however complicated, have yet been found which cannot be deduced as consequences of the assumption of the existence of a space-occupying medium, capable of having produced in it a wave-motion, but subject to affection by the presence of material substances. It is difficult at first for the non-scientific mind to grasp the idea that space, as we call it, may thus be full of an ever moving, but non-tangible, material, and that, in truth, no such thing as a true vacuum, or space absolutely void of everything, does or perhaps can exist.

Another line of argument leading to the same conclusion is found as follows: One of the great intellectual triumphs of the nineteenth century has been the elaboration and proof that, in association with mere material substances, we have something else called energy, which we can neither create nor destroy, but which presents itself under many forms. Energy, like matter, is subject to a law of conservation; that is to say, we are unable, by our unaided human powers, to alter the total amount of it. Energy, however, must be thought of as an entity or measurable article, which can exist in many diverse types, and which can be transformed from one type to another. A swiftly moving train or cannon ball, for instance, is an exhibition of energy in association with matter, but this particular form of energy can only be obtained by the transformation of some other kind of energy; in the one case, by putting out of existence the energy associated with a given weight of coal in air, and, in the other, with a given mass of gunpowder. We have no experience of Energy separated from Matter of some kind, and we do not know whether they can so exist. Without entering into discussions beyond the region of physical science, it may be sufficient for our purpose to state that, in modern Chemistry and Physics, Matter is regarded as the vehicle of Energy. Hence, if we find Energy passing through space, or associated with that which we are in the habit of calling empty space, we can only conceive of it as so doing if there is something there to carry or convey it. In order that a wave-mo-

tion or impulse may be communicated through a material medium, it must possess elasticity and inertia. In virtue of the first, it resists some kind of deformation, and, in consequence of the latter property, its parts tend to continue moving when once in motion. We see this in the case of water. The water surface resists being heaped up or made unlevel, and it persists in motion when once moved. Hence, it can have waves produced on it, varying from ripples to billows in wave-length. In the same way the air resists compression and expansion, and it also possesses inertia. Accordingly, it can have a pulsatory or wave-motion produced on it, and this constitutes sound, when it affects our organs of hearing. The known fact that wave-motion can exist in the ether led philosophers, therefore, to conclude that ether possessed properties analogous to elasticity and density. But no one had been able to show, by direct experiment, that ether had those qualities, because it only affects, indirectly, one organ of sense, the eye, and that only by reason of the existence of waves in it of a certain wave-length.

Clerk Maxwell, however, was led by profound reasoning to the conclusions, that the qualities of the ether which correspond to that which we call the elastic pliability of matter, and its density or massiveness, are in reality the electric and magnetic qualities of space, in virtue of which it permits an electric displacement to be made through it, and also what is called a magnetic flux. Faraday had shown that the process commonly called charging a conductor with electricity, was in reality only the effect of producing in the surrounding insulator an electric strain or polarization, subsequently called an electric displacement. This displacement is produced by an agency called electric force; and, when the force is removed, the displacement disappears. The quality of the space, whether filled with matter or ether, which permits the electric displacements to take place under the action of the electric force, is called its electric pliability.

In the same manner, Maxwell identified the other well-known property of space, in virtue of which magnetic force can create in it a state called magnetic flux, as the analogue of the density or inertia of matter. This quality is called the magnetic permeability. Building upwards from well known facts, Maxwell showed that, since space filled only with ether has these two qualities of electric pliability and magnetic permeability, it

should be possible to produce as free ether waves by means of electric force, and that these electric waves would be propagated with the velocity of light.

This magnificent theory remained, however, unverified, experimentally, until 1887, when Heinrich Hertz gave to the world the results of his splendid researches on the production of electric waves. Hertz showed that, if two conductors were charged, respectively, with positive and negative electricity, and then allowed to discharge each other with the production of a small electric spark between them, this action produced, under proper conditions, an electric wave which was propagated out into space. Just as a stone dropped into water makes a splash when it enters the surface, and generates a series of expanding ripples, so the electric spark, under certain conditions, makes what is virtually a splash in the ether, and sends out a series of ether waves. A spark of this kind is called an oscillatory spark. In order to detect these waves, Hertz invented a receiver or detector, consisting of a nearly closed loop of wire, the ends being furnished with metal balls almost touching one another. When held in a proper position, the passage of an electric wave through this Hertz detector creates a minute spark between the balls. Aided by this apparatus, Hertz showed that these electric waves possessed all the properties of light, although unable to affect the eye. They moved with the same speed and could be reflected, and refracted, like rays of visible light. Lodge, Fitzgerald, Trouton, Sarasin, de la Reve, Bose and many other physicists extended these results, and proved an absolute identity in nature between the rays of light by which we see and these invisible Hertz waves.

Subsequently to Hertz's lamented early death, others have invented and improved the means of detecting Hertz waves. Of notable importance was the observation of Professor Calzecchi Onesti, of Fermo, in 1885, and Professor E. Brauly, of Paris, in 1891, that a mass of metallic filings or powdered metal is a nonconductor of the electric current in its ordinary state, but may become converted into a conductor when an electric wave falls upon it. This device, modified and improved, now forms the sensitive organ or artificial eye for seeing and detecting these Hertz waves. It is usually called a coherer.

Starting from these known facts, Marconi began, a few years ago, to elaborate the details of his system of wireless telegraphy,

and to make additions by which delicate, uncertain and difficult laboratory experiments were converted into practical processes, possessed of all the qualities of certainty and precision which are the essential conditions for industrial use. The most important addition which he made to knowledge, was the discovery that the coherer becomes vastly more sensitive to the presence of ether waves, if it has attached to its ends two long wires; or, better still, if it is inserted in between a long vertical wire and the earth. Marconi's present arrangements, therefore, for wireless telegraphy are as follows:—At each of the two stations between which communication is to be made, a long rod or wire is set up. This wire is, generally, a stranded copper cable, well insulated, and is attached either to a flagstaff or the mast of a ship, or hung from a chimney, tower or cliff. The height of this wire is determined by the distance to be worked over. At present, Marconi finds that a rod twenty feet high enables him to signal one mile, one forty feet high four miles, one eighty feet high sixteen miles, and so forth. He is, however, continually making improvements, which have for their object the reduction of the necessary height of rod. At each station, there is also established the receiving and transmitting apparatus. The latter consists of an induction coil, technically termed a ten-inch spark coil, and it is provided with two spark balls. The coil is worked by a battery of dry cells; and, when in action, it creates an electric discharge between the two spark balls in the form of a bright electric spark. These spark balls are placed half an inch apart. In the circuit of the battery is placed a contact key, by pressing which the operator can set the coil in action and make electric sparks, or rather series of sparks, of long or short duration.

The operation of transmitting ether waves is then as follows:—The long vertical wire is connected to one terminal or spark ball of the coil, and the other spark ball is connected by a wire with the earth. On pressing the key, a torrent of sharp, crackling sparks passes between the balls, and in the long vertical wire electrical oscillations are set up which result in a series of electric waves being sent out into space. The duration of this wave production can be determined by making long or short contacts with the key. We must, therefore, think of this long wire as a kind of organ pipe, which emits ethereal music, and sends out an ether wave train of long or short duration, just as a fog horn

sends out sound waves, when sound signals are made at sea. The receiving instrument consists of a very sensitive coherer. In a small glass tube are fixed two silver wires which nearly touch, and the interspace is occupied with a minute quantity of finely powdered nickel and silver. Marconi has introduced numerous improvements into the manufacture of this appliance, and each of his coherers is tested most carefully, prior to use at signalling stations. The sensitive tube is joined in series with a battery and a telegraphic relay, this last being an apparatus for setting in action an ordinary telegraphic Morse printing instrument by means of an exceedingly feeble electric current. When it is desired to receive signals, the sensitive tube has one end connected to the long vertical wire and the other to the earth. The waves sent out from the distant station then fall upon the vertical receiving wire, run down it and affect the coherer, causing it to become a conductor for the moment, and so permits a feeble current to pass through it, which, through the action of the relay, is made to print a signal upon a strip of paper. This signal is either a dot or a dash, according to the period during which ether waves are falling upon the wire. After each signal, the coherer is brought back to its original condition by a tap administered automatically by a little hammer. Thus pressures, long or short, upon the key of the induction coil at the distant place, cause marks, long or short, to be made upon a paper strip at the receiving instrument, and these are interpreted into intelligible signals in accordance with the recognized Morse code.

Such, then, in outline, is the system which Marconi has developed for utilizing ether waves for telegraphic purposes. It remains to indicate briefly its limitations and possible uses.

Marconi's experiments at the South Foreland Lighthouse, where a flagstaff 150 feet high was erected, in correspondence with a similar one in France—a vertical insulated wire being also run up the mast of the East Goodwin Lightship, with which communications are held—are being conducted in a little room not ten feet square, which is part of the dynamo and engine house of the Lighthouse. On a small deal kitchen table stands the apparatus for transmitting and receiving, the value of which, excluding the flagstaff, would easily be covered by five hundred dollars. Here, all day, for the past few weeks, experiments have been conducted without the smallest hitch or failure.

At the rate of fifteen or eighteen words a minute, messages are flashed backwards and forwards between the operators, sitting on either side of the Channel. Neither fog, rain, mist nor driving storm interrupts the communication. Marconi says that the signals are even better and sharper during rain. Not only is there communication with France, but even more important with the Goodwin Lightship. The operator on board the ship can call up and ring an electric bell at South Foreland by simply touching his key. The Lighthouse is in telephonic communication with the Ramsgate Lifeboat House. An attendant now sleeps by the instrument at South Foreland. If the East Goodwin Lightship, twelve miles off, notices signals of distress from any ship caught in the destroying grip of those terrible sands, one touch on the key suffices to call up the attendant at South Foreland, and a short message notifies the whereabouts of the wreck. The South Foreland telegraphist then telephones down to Ramsgate and dispatches the Life Boat on its rescuing errand. Quite lately the Trinity House Brethren have made a most careful inspection of the system, and were very favorably impressed with its simplicity and certainty. It can only be a matter of time before every lightship and lighthouse will be kept in touch with the coast.

It has been contended that this method of telegraphy has no utility, because each receiver can be disturbed by vagrant ether waves made in the neighborhood. This objection, however, has very little force. Ordinary telegraphic communication with wires could also be upset if mischievous persons cut wires or sent private electric currents into them. Public opinion and a few simple legislative enactments will, however, be sufficient to meet this supposed difficulty.

The creation of a complete independence for each station, and the localization of the wave or determination of its field of action, have not yet been entirely achieved. Where two transmitting stations are at very different distances, it is always possible to differentiate their actions by the use of two receiving rods of different heights at the receiving station. Thus, if at South Foreland two rods were set up, one 150 feet high and one 70 feet high, each with its receiving instrument, the attendant at South Foreland could distinguish signals from France twenty-eight miles away or the Goodwins twelve miles away, as follows: If both receivers acted, then he would know the signals were

coming from the Goodwins, and he would switch off the longer rod and cut France out of circuit. If only the receiver of the longer rod acted he would then know the signals were coming from France. Signor Marconi has made some progress in utilizing reflectors for limiting the direction of the wave, but there is still a great field open for invention.

Lastly, one or two words must be said as to the immediate future of the invention. There is no question that for communication between ships at sea, between lightships and lighthouses and the shore, and between ships and coast guard stations there is a wide field of utility open to it at once. It will economically replace short submarine cables in a few instances, or perhaps be supplementary to them in case of breakdown. It will enable communication to be cheaply established to islands and places where the traffic is not great enough to carry the expense of a submarine cable, and it will, without doubt, be adopted in some form in naval and military operations. It will never replace entirely telegraphy with wires, because the use of the continuous wire secures a privacy not otherwise to be obtained. From one point of view, the difference between wireless telegraphy and telegraphy with wires is the same as the difference between a post card, or open letter, and a sealed one. The continuous wire is like the envelope of the letter. It prevents the diffusion of the information beyond certain limits. The future, however, will slowly unroll the scope and limitations of this new telegraphy. Its practical uses are indubitable, but it has a wider interest from a scientific standpoint, in that it opens up a vista of fascinating speculation as to the possible revelations in store for us concerning the powers and potencies of this mysterious ether.

Archæologists speak to us of a stone age, a bronze age and an iron age in the history of the world; but the Twentieth Century will surely claim the title to be called the Ether Age, as "knowledge grows from more to more" concerning the nature of this universal, hidden and yet most subtle, medium, in which ripples are the revealing rays of light, and billows are the ether waves we are learning to employ.

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